TABLE 1.—*Total number of days with rain from each type at San Diego, and total amounts from each type at San Diego, Cuyamaca, Warner Springs, during the last five seasons*

Month	North Pacific				South Pacific				Interior				Mexican			
	San Diego		Cuyamaca	Warner Springs	San Diego		Cuyamaca	Warner Springs	San Diego		Cuyamaca	Warner Springs	San Diego		Cuyamaca	Warner Springs
	Days	Amounts	Amounts	Amounts	Days	Amounts	Amounts	Amounts	Days	Amounts	Amounts	Amounts	Days	Amounts	Amounts	Amounts
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.24	0.38
August	0	0	0	0	0	0	0	0	4	.08	0	0	2	.03	3.03	5.17
September	0	0	0	0	0	0	0	0	1	.04	.05	.01	2	.22	5.30	1.94
October	0	0	0	0	0	0	0	0	3	.41	3.52	2.01	2	1.10	5.52	2.95
November	10	1.66	5.26	2.02	3	.37	1.03	.51	6	1.11	6.35	2.60	2	.78	.63	.41
December	17	5.85	22.97	6.78	5	1.68	2.97	1.52	3	.85	7.72	3.21	0	0	0	0
January	39	11.83	30.04	11.40	7	2.46	13.63	6.08	0	0	0	0	0	0	0	0
February	11	2.05	13.45	4.62	11	5.77	13.68	8.40	10	3.26	11.04	6.69	0	0	0	0
March	9	1.40	5.29	1.87	3	.34	2.09	.51	14	3.11	7.65	3.99	0	0	0	0
April	10	.96	7.99	3.32	0	0	0	0	13	4.30	12.07	4.03	0	0	0	0
May	10	.84	5.51	1.35	0	0	0	0	10	1.80	9.43	5.26	0	0	0	0
June	0	0	0	0	0	0	0	0	4	.12	.16	.06	0	0	.08	0
Total	106	24.59	90.51	31.36	29	10.62	33.40	17.02	68	15.08	57.99	27.86	8	2.13	15.80	10.85
Percent	50	47	46	36	14	20	17	20	32	29	29	32	4	4	8	12

TABLE 2.—*Total number of days with rain and percentages at San Diego, and total amounts and percentages from each type by seasons at San Diego, Cuyamaca, and Warner Springs*

NORTH PACIFIC

Season	San Diego				Cuyamaca		Warner Springs	
	Days	Percent	Amounts	Percent	Amounts	Percent	Amounts	Percent
1928–29	25	60	5.12	73	25.05	70	8.78	71
1929–30	19	43	4.01	37	15.34	37	5.09	25
1930–31	14	39	4.47	41	8.48	32	3.25	27
1931–32	26	53	6.86	52	30.23	57	8.86	36
1932–33	22	55	4.13	39	11.41	28	5.38	32

SOUTH PACIFIC

1928–29	1	2	0.10	1	0.73	2	0.28	2
1929–30	6	14	1.51	14	8.95	21	4.76	23
1930–31	11	30	4.42	41	7.40	28	4.87	41
1931–32	5	10	2.07	16	8.41	16	4.60	18
1932–33	6	15	2.52	24	7.91	20	2.51	14

INTERIOR

1928–29	15	36	1.86	26	9.77	28	3.16	28
1929–30	17	39	4.99	47	12.30	30	6.89	33
1930–31	11	31	1.89	18	9.29	35	2.96	25
1931–32	15	31	3.46	26	11.38	21	8.66	34
1932–33	10	25	2.88	27	15.30	38	6.19	36

TABLE 2.—*Total number of days with rain and percentages at San Diego, and total amounts and percentages from each type by seasons at San Diego, Cuyamaca, and Warner Springs*—Continued

MEXICAN

Season	San Diego				Cuyamaca		Warner Springs	
	Days	Percent	Amounts	Percent	Amounts	Percent	Amounts	Percent
1928–29	1	2	0.02	0	0	0	0.08	1
1929–30	2	4	.22	2	5.06	12	3.87	19
1930–31	0	0	0	0	1.61	5	.78	7
1931–32	3	6	.79	6	3.61	6	3.02	12
1932–33	2	5	1.10	10	5.52	14	3.10	18

TABLE 3.—*Precipitation and departures from the mean at San Diego, Cuyamaca, and Warner Springs during the last five seasons*

Season	San Diego		Cuyamaca		Warner Springs	
	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure
1928–29	7.10	−2.65	35.55	−3.25	12.30	−5.48
1929–30	10.73	+.98	41.65	+2.85	20.61	+2.83
1930–31	10.78	+1.03	26.78	−12.02	11.86	−5.92
1931–32	13.18	+3.43	53.58	+14.78	25.14	+7.36
1932–33	10.63	+.88	40.14	+1.34	17.18	−.60

HOURLY FREQUENCY AND INTENSITY OF RAINFALL AT SAN FRANCISCO, CALIF.

By R. C. COUNTS, Jr.

[Weather Bureau, San Francisco, Calif., August 1933]

[Compare: McDonald, W. F., Hourly Frequency and Intensity of Rainfall at New Orleans, La. MO. WEA. REV., January 1929, vol. 57, pp. 1-8]

The hourly rainfall data for San Francisco present several aspects, the most interesting of which is the decidedly greater frequency of rain during the late night and early morning hours than at midday or in the afternoon. This phase of the rainfall has long been a subject for comment, even by comparative newcomers to this area, but heretofore neither the exact facts nor their causes were known, and comment was based largely on conjecture. Data have been compiled for the 20-year period, 1911–30, which, it is believed, is of sufficient length to at least greatly reduce any effects resulting from pronounced abnormalities. The data were tabulated from the daily records of the local Weather Bureau office. These records contain not only the times of beginning and ending of precipitation but also the hourly amounts, which were extracted from the 24-hour record sheets of a self-recording rain gage of the tipping bucket type. Each 0.01 inch is registered on the sheets in the proper hour division, but occasionally this unit amount may be recorded in 1 hour yet be an accumulation of rain extending over several hours; especially is this true of a drizzle or heavy mist. It is reasonable to believe, however, that such cases are as numerous in any hour as another and that the relation of the total hours with a measurable amount, or the total hourly amounts, is unaffected.

In the first compilation the individual hours with 0.01 inch or more, by months, in the 20 years were counted. The sums obtained showed the trend of the hourly frequency for each of the calendar months but the sums for no month were strictly comparable with those of any other because of the variation in length of the months. To obviate this the sums were reduced to a percentage basis, shown in table 1, by dividing the total hours with a measurable quantity of rain by the total number of hours. In the 31-day months the possible hours for each of the 24 were 620, in the months of 30 days there were 600, and in February, 5 of which were in leap years, the divisor was 565. The annual hourly frequency percentages were found by dividing the number of rainy hours of the same name in all months by the possible 7,305 hours to obtain greater accuracy than the means of the monthly hourly percentages would have given.

TABLE 1.—*Hourly frequency of precipitation, 0.01 inch or more (percentage of possible), 1911–30*

	A.M.												P.M.											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
July	0.	0.2	0.5	0.2	0.5	0.	0.2	0.2	0.6	0.	0.2	0.2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
August	.3	.3	.3	.2	.2	0.	0.	0.	.3	0.	0.	.2	.2	.2	.2	0.	0.	0.	0.	0.	.2	0.	0.	.2
September	1.0	1.2	1.2	1.5	1.3	1.5	1.2	.5	.8	.7	.7	.8	.7	1.0	1.7	1.2	1.2	.5	1.0	.7	1.0	.8	.7	1.0
October	2.1	1.8	2.4	3.2	4.0	2.9	2.6	2.6	2.4	2.4	1.6	1.9	1.3	1.1	1.1	1.5	2.4	1.8	1.6	2.9	2.6	1.8	1.8	2.3
November	5.7	6.2	6.7	7.2	7.3	5.5	5.8	5.3	5.5	5.0	5.7	5.3	4.7	4.7	4.0	5.5	6.5	5.7	4.7	5.2	5.7	4.7	4.8	4.8
December	8.9	8.7	9.4	8.7	8.9	8.4	8.9	9.0	8.5	8.4	8.2	7.9	9.2	8.9	7.6	7.9	8.5	7.6	9.0	7.6	8.5	8.4	9.7	9.5
January	11.8	12.1	11.0	12.1	13.2	11.9	13.5	12.3	11.5	11.0	9.7	10.6	9.5	10.8	8.2	8.5	8.9	8.7	9.2	9.4	9.5	10.0	10.5	10.2
February	12.7	12.9	13.1	11.9	9.9	9.0	10.3	9.6	9.4	7.6	7.6	7.1	7.8	7.4	8.5	10.8	10.1	8.5	9.7	9.7	9.2	10.3	11.3	11.5
March	7.1	7.1	6.9	7.6	8.2	6.5	6.8	8.9	7.3	6.1	4.7	5.2	6.3	5.6	5.2	5.6	5.6	6.5	6.0	6.0	5.8	5.8	5.6	6.3
April	4.5	4.5	5.5	4.8	4.3	3.8	4.0	4.8	4.5	4.0	3.5	2.7	2.5	2.7	3.0	3.7	3.0	2.2	3.0	3.0	2.8	3.5	3.0	3.2
May	1.8	2.9	2.4	3.1	2.7	2.6	1.9	2.4	2.6	2.1	1.8	1.5	1.0	1.9	1.5	1.5	1.6	1.8	1.6	2.1	1.9	1.9	1.3	1.6
June	.7	1.0	1.7	.8	.7	.3	.5	.7	.3	.7	.5	.5	.7	.3	.7	.5	.7	.5	.5	.5	.5	1.0	1.2	1.0
Year	4.7	4.9	5.0	5.1	5.1	4.4	4.6	4.7	4.5	4.0	3.7	3.6	3.6	3.7	3.4	3.8	4.0	3.6	3.8	3.9	4.0	4.0	4.1	4.3

Ninety percent of the rain at San Francisco occurs from November to April, inclusive, and as the weather of these months is characteristically the same and the percentages of the hourly frequency of each are in the same ratio as the annual figures, it is necessary to discuss the latter only. The annual hourly percentages in table 1 and the curve in figure 1 reveal one diurnal maximum and one minimum. The maximum begins near midnight and ends about 9 a.m., while the minimum extends over the period from the late forenoon to early evening. Another distinguishing feature of the data is the suppression of the afternoon secondary maximum, which is typical of the greater portion of the United States inland from the Pacific coast.

This afternoon increase in hourly frequency, which is only slightly evident in San Francisco, is the result of

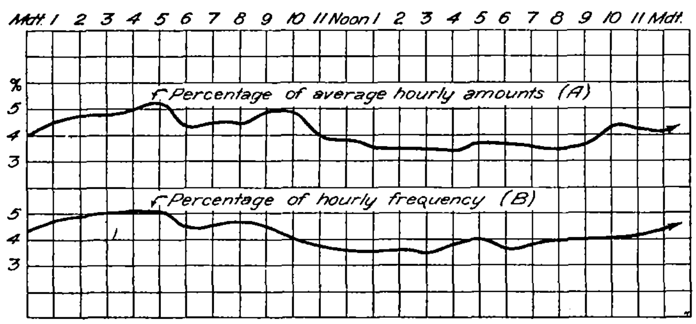

FIGURE 1.

showers initiated by convection, generally on warm summer afternoons. But the thermal stratification and pressure distribution over and contiguous to California are unfavorable to the development of precipitation in the lowlands of the State during the summer. Too, the climate of the San Francisco Bay area is essentially marine, so that it is overlain by a stratum of marine air varying in depth from a few hundred to three or four thousand feet, over which, during most of the summer, day and night, there is a layer of air of a considerably higher temperature and lower water vapor content. Convectional type showers cannot develop under such conditions, either in the afternoon or at any other time of the day. Infrequently, and usually in the spring and autumn, the marine air in this bowl is superseded by air of continental origin, which descends from the expansive plateau to the eastward and attains a high temperature from the resulting compression, but is of low water vapor content. This afternoon maximum, however, is reflected to a negligible extent in the wet months.

The frequency of rainfall is greatest in any 12-hour period from 9 p.m. to 9 a.m., when 55 percent of the hours with a measurable amount are tabulated, while during the period 9 a.m. to 9 p.m., only 45 percent of the hours are tabulated. In this period extending throughout the night and early morning, the hourly rainfall expectancy is more than 20 percent greater than during the remainder of the day. In the hours when the sun is above the horizon, which averages in the 6 wet months, to the nearest hour, 7 a.m. to 6 p.m., there is an average of 251 hours in the 20 years with 0.01 inch or more, but an average of 283 at night. On this basis the rainy hours are about 13 percent more numerous at night than in the daytime. Of the total number of hours with measurable amounts 38.2 percent are accumulated in an 8-hour interval from midnight to 8 a.m., while only 29.4 percent are spread over an equal period from 10 a.m. to 6 p.m., and the remaining 32.4 percent distributed uniformly in the intervening hours. This discrepancy in the hourly distribution discloses a 30 percent greater hourly frequency of the night period over that of the late forenoon and afternoon and it probably is the wide variation between approximately the hours constituting these two periods that is responsible for the unequivocal impression in the public mind. Rain in measurable amounts occurred in 372 of the possible 7,305 hours between 4 and 5 a.m., a percentage of 5.1, but between 2 and 3 p.m., there were only 251 rainy hours, or 3.4 percent of the possible. This extreme hourly range reveals that rain fell in this night maximum hour 50 percent more often than in the minimum hour of the afternoon.

In the second tabulation the amounts of precipitation in each hour of the day of each month were added together. By dividing these hourly amounts by 20, hourly means were obtained (see table 2). These show that rainfall is also heavier in the night hours than during the daytime. The total amounts (in inches) in each hour of all months were divided by 404.64 inches, the total precipitation at all times in the 20 years, to reduce them to an annual percentage basis, shown by curve (A) in figure 1. This curve is virtually coincident with that representing the percentage of hourly frequency. The diurnal maximum and minimum and the apparent anomaly near 6 a.m. are as definite as in the frequency curve in the same figure. Obviously, the cause operating to bring about this disequilibrium between the frequency of day and night likewise influences the intensity.

TABLE 2.—*Mean hourly rainfall, 1911–30, inclusive*

	A.M.												P.M.											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
July	x	x	x	x	x	x	x	x	x	0.01	x	x	0	x	0	0	x	x	0	0	x	x	x	x
Aug	x	x	0.01	x	x	0	0	x	0	x	0	x	x	x	x	0	x	x	x	x	x	x	x	x
Sept	0.01	0.01	.02	0.02	0.02	.02	.01	0.01	.01	.02	.01	0.01	.01	0.01	.01	.02	0.02	.02	.01	x	0.01	0.01	0.01	0.01
Oct	.04	.03	.04	.07	.08	.05	.04	.03	.05	.04	.03	.03	.01	.02	.02	.02	.03	.03	.03	.03	.03	.02	.03	.03
Nov	.09	.11	.10	.11	.09	.09	.08	.10	.13	.19	.12	.09	.08	.07	06	.05	.10	.08	.08	.08	.07	.13	.11	.09
Dec	.16	.16	.16	.18	.12	.14	.14	.16	.18	.12	.15	.17	.17	.17	.20	.14	.17	.19	.21	.13	.16	.18	.18	.16
Jan	.21	.23	.26	.24	.32	.20	.20	.18	.23	.20	.16	.18	.17	.18	.14	.11	.13	.15	.15	.16	.16	.19	.20	.18
Feb	.21	.23	.18	.16	.19	.16	.21	.20	.16	.16	.13	.15	.12	.08	.13	.16	.16	.14	.11	.14	.15	.16	.20	.21
Mar	.12	.08	.08	.09	.12	.13	.15	.10	.11	.13	.10	.08	.09	.10	.06	.09	.08	.07	.08	.10	.11	.11	.09	.10
Apr	.05	.07	.07	.07	.07	.05	.07	.10	.08	.08	.04	.03	.04	.03	.05	.07	.03	.02	.03	.04	.03	.07	.05	.04
May	.02	.04	.04	.04	.04	.02	.02	.03	.03	.04	.03	.03	.02	.02	.02	.03	.02	.01	.02	.02	.02	.01	.01	.01
June	.01	.01	.02	x	x	x	x	x	x	.01	.02	.01	.01	x	x	x	x	x	x	x	.01	.01	.01	x
Mean	.08	.08	.08	.08	.09	.07	.08	.07	.08	.08	.07	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.07	.07	.07

x=less than 0.005 inch.

The cause of the more frequent occurrence, and also of the excessive intensity, of precipitation at night is, unquestionably, nocturnal cooling. Observations and studies by meteorologists in recent years show that radiation is a principal factor in the formation and physics of clouds whereas previously it was conceded to be of only minor importance. In a paper, The Summer Nighttime Clouds in the Santa Clara Valley, California,[1] E. H. Bowie ascribes the formation of these clouds to the cooling resulting from the excess of the emitted over the absorbed radiation. His conclusion is as follows: "* * * the formation of stratus clouds over the Santa Clara Valley during the summer is to be regarded as a radiative phenomenon, occurring when the valley is flooded by air of marine origin, rich in water vapor, and when it in turn is overlain by air of quite low humidity. When this situation exists the excess of the outgoing over the incoming radiation is at its maximum at the upper surface of the bay of marine air, and sometime during the night the cooling thus caused reaches the dewpoint, condensation starts and the cloud forms."

If radiation from a moisture-laden layer of air is such a potent factor in the formation of stratus clouds, it follows that radiation must influence, either directly or indirectly, the formation of clouds during a cyclonic regime. After clouds have formed they tend to become unstable as a result of radiation and absorption. D. Brunt[2] gives some estimates of the exchanges of heat by radiation and absorption which show the effect of these in inducing instability in clouds. His theoretical considerations indicate that "at night the base of a sheet of cloud, in virtue of its possessing the radiative properties of a black body, should absorb more heat than it radiates downward, while the top of the cloud sheet should lose more heat by radiation upward than it gains by absorption of the downward moving radiation. Within the cloud sheet the net flow of heat upward or downward is very slight, on account of its black body properties * * * Hence we need only consider the exchanges of heat between the upper surface of the cloud and the atmosphere above it, and between the lower surface of the cloud and the atmosphere and earth beneath it." He cites the observations of Ångström as substantiating his equations for the net exchanges of heat. The net loss from the upper surface of low cloud is about one third of the black-body radiation, nearly one half for medium cloud, and a slightly greater fraction for high cloud. The net gain at the lower surface is roughly proportional to the height, being very small for low cloud. It follows that the tendency towards instability will be more marked in high than in low cloud and would arise largely at the upper surface only of low cloud.

The cooling of a moisture-laden stratum of air by radiation is a maximum at the upper surface and decreases with descent into it. Indeed the temperature might even rise at the lower surface due to absorption of radiation from another stratum of water vapor or cloud below it, or the ground, although this heating would be small in the lower half of the troposhpere. Under favorable conditions cooling throughout the moisture-laden stratum continues until the lapse rate equals that of the adiabatic for dry air, after which any further cooling establishes a superadiabatic temperature gradient and forces turbulence. Although stratus, and many other clouds, do not yield precipitation, or at most only mists, light dirzzles or snow flurries, because of the absence of vigorous ascending currents, nevertheless a layer of air of considerable thickness and heavily laden with water vapor may yield both cloud and precipitation through vertical convection induced, as explained, by its nocturnal cooling. The forecaster is not infrequently confronted with an obvious unstable condition not connected with a cyclonic system in which precipitation occurs during any hour of the day or night. Is it probable that radiation from air of the necessary water vapor content frequently may create this unstable condition through the establishment of a superadiabatic temperature gradient in one or more of the strata. But whatever the origin of instability it does not seem presumptuous to suggest that continued loss of heat from a deep layer of saturated or nearly saturated air may establish vertical convection sufficiently persistent and vigorous to cause precipitation.

The effect of radiation is not confined to instability rain alone but may hasten and intensify cyclonic and orographic precipitation. In a cyclonic process the current of relatively warm moist air is forced to ascend either by overrunning a surface stratum of denser air or by being itself underrun by a colder, heavier mass. In either case dynamical cooling and hence condensation are resultants of the expansion of the rising air. Along the Pacific coast these effects are amplified by orographic features, but the cooling is not unlike that due to a loss of heat by radiation. As the rising air cools by expansion it loses heat simultaneously by radiation to the atmosphere above. The latter effect causes acceleration of the rate of decrease of temperature and a shortening of the time between the beginning of the process and the attainment of the dew point. Condensation follows, but radiation

[1] Monthly Weather Review, February 1933, vol. 61, pp. 40–41.

[2] Notes on Radiation in the Atmosphere, Quarterly Journal, October 1932. R.M.S., pp. 389–418.

continues now from the cloud and intensifies the process involved in forming drops.

It must be concluded that radiation is a factor in all rain-making processes but the methods by which it induces or influences precipitation are necessarily complicated and imperfectly understood. The slightly greater loss of heat by radiation from water vapor or cloud at night unquestionably accounts in part for the more frequent and heavier nocturnal precipitation. C. S. Durst[3] has ventured the following hypothetical explanation of a possible action of radiation:

Below the critical height,[4] however, any particle which forms will lose heat by radiation and will consequently tend to cool the air in its neighborhood with the effect of increasing the deposition of ice or water. Thus above this critical height condensation will tend to be evaporated; below it, drops will tend to grow, until they either fall through the surrounding atmosphere or reduce its temperature to such an extent that instability arises.

Whatever the ways in which radiation influences cloud formation or precipitation, it remains that data about radiation from water vapor in the free air are essential to a better understanding of the processes involved.

[3] Quarterly Journal, R.M.S., April 1933, vol. 59, pp. 125-129.

[4] The height below which there is a net loss of heat by radiation and above which there is a net gain of heat by absorption of radiation from below; above 6 km in southeast England.

NACREOUS AND NOCTILUCENT CLOUDS

By W. J. HUMPHREYS

[Weather Bureau, Washington, September 1933]

Two interesting and important papers recently have been published by Carl Störmer [1] on clouds in the stratosphere, a region commonly free from clouds of every kind.

There are two types of these clouds:

a. The nacreous (from the name common to several languages for mother-of-pearl), figure 1, which occurs at heights of 20 to 30 kilometers above sea level, and

b. The noctilucent (a name already well established), figure 2, which forms at about 80 kilometers above the earth.

The first of these, the nacreous, resembles in places an alto-cumulus lenticularis, or, more exactly, an alto-stratus lenticularis, though presumably it contains much less cloud material than either of these generally does, and is brightly colored like a glorified iridescent cloud. The second, or noctilucent, type seems usually, if not always, to resemble some sort of cirrus. It is silvery, or bluish-white, in color and has been seen in the middle to high latitudes of both hemispheres, but only when the lower atmosphere was in the shadow of the earth and the cloud in full sunshine.

Both these types of stratospheric clouds had been observed and carefully studied long before Störmer made the detailed measurements of them that form the basis of his valuable papers mentioned above; one, the nacreous, by H. Mohn, as early as 1871, and the other by O. Jesse as far back as 1885. Nevertheless their origin still is in doubt.

I propose here to develop a tentative hypothesis as to the origin of these clouds. It may be incorrect, and much of it is old, but even so a logically possible origin, however wide of the mark, is a better aid to the memory than no origin at all, and secures a more willing acceptance of the facts. This hypothesis is that they are produced by the condensation of water vapor just as are all the clouds of the lower atmosphere.

As is well known the stratosphere commonly is 25° C., or thereabouts, warmer, and its base several kilometers lower in high latitudes than in tropical regions. Owing to this temperature difference there obviously must be an interzonal (equator to poles and poles to the equator) circulaton in the stratosphere. Calculation indicates that near the height of 20 kilometers the pressure should be roughly constant the world over and the winds at that level therefore nearly zero, as observation shows them to be. Below this level of equal pressure and mininum wind velocity the air of the stratosphere must flow from the lower to the higher latitudes and next above it, to what height we do not know, counterwise or toward the tropical regions. Evidently this circulation necessitates a corresponding ascent of the air in the stratosphere over high latitudes, with, of course, a greater or less loss of temperature with increase of height. The lapse rate however will be kept small by radiation from below, provided the circulation is gentle.

Suppose the base of the stratosphere at latitude 60° N., say, is 10 kilometers above sea level; that at this level, and just above it, saturation obtains; that the temperature here is 228° A., and that the lapse rate in the stratosphere is zero up to 18 kilometers and then uniformly positive in the region where convection presumably is active. At what temperature would saturation over water (water assumed because these clouds are iridescent, implying diffraction by spherical droplets) occur in this air (specific humidity, or vapor fraction of air, constant) at the height of 25 kilometers, the level, roughly, of the nacreous clouds?

A little calculation shows this to be of the order of 205° A., a temperature that would be approached at the given height if the air in the stratosphere above the 18-kilometer level had a lapse rate of 2.9° C. per kilometer. If the initial relative humidity were only 50 percent instead of 100 percent as assumed, then saturation would occur at the same height, 25 kilometers, if the lapse rate were 3.6° C. per kilometer.

Hence, under the conditions here specified, most of which are in agreement with observations and none contrary thereto, it seems quite possible that in rather high latitudes a thin cloud might be formed in that portion of the stratosphere in which the upward component of the stratospheric interzonal circulation is most pronounced.

So much for the presumable origin of the nacreous cloud. It remains now to consider the noctilucent cloud. Assume that occasionally, at least, in fairly high latitudes the temperature of the upper air is: from 10 to 18 kilometers, 228° A.; from 18 to 25 kilometers, decreasing uniformly to 210° A., from 25 to 35 kilometers, 210° A.; from 35 to 40 kilometers, increasing uniformly to 315° A.; from 40 to 60 kilometers 315° A., and beyond this last level decreasing, 7° C. per kilometer, to an undetermined height. Also let the water vapor at every level be one part in 4,000 of all the gases present, the amount we have assumed to be present at the base of the stratosphere. Also let the composition of the air be substantially constant from the base of the stratosphere up to 100 kilometers, or more, above sea level, except for the variation in the amount of ozone present, the substance responsible for the high temperature, if it exists, at the levels of 40 to 60 kilometers. These suppositions are in harmony with the skip phenomenon of distant, loud sounds, and ozone and auroral observations. Then, if these assumptions are correct, saturation over ice (ice because these clouds do not show iridescence) could again occur and cloud begin to form at a height of 80 to 83 kilometers, roughly, and temperature of about 160° A.

[1] Höhe und Farbenverteilung der Perlmutterwolken, Geofys. Pub., vol. IX, no. 4, Oslo, 1932.
Height and Velocity of Luminous Night-Clouds Observed in Norway, 1932. Univ. Obsy. Oslo, 1933.